PATENT ABSTRACTS OF JAPAN

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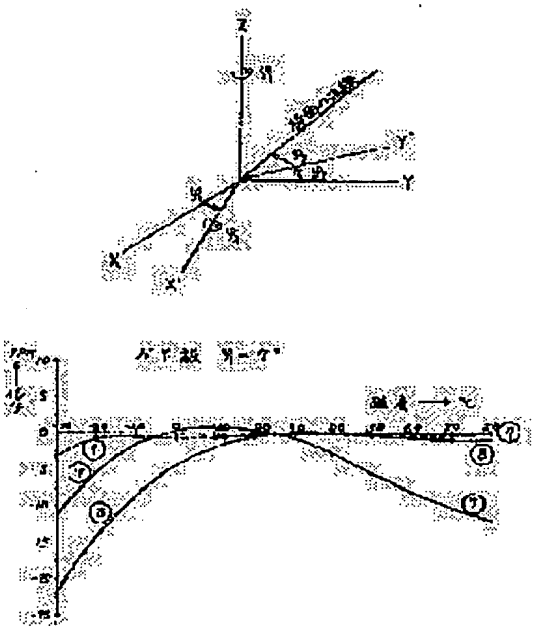
(54) CRYSTAL VIBRATOR

(57)Abstract:
PROBLEM TO BE SOLVED: To provide a new crystal vibrator which is cut out with a comparatively small cut-out loss and has a frequency temperature characteristic where the width of a frequency change is reduced over a wide temperature range, the crystal vibrator is in use practically in the case of the normal use without compensation and obtains more excellent matching with a similarity with the shape of a frequency temperature characteristic of the wide variety of kinds of oscillation circuits when any compensation is required.
SOLUTION: The crystal vibrator uses a crystal plate where an angle (ϕ2) of a normal onto the crystal plate face is within a range of a reference angle from 35° 10' to 36° 50' at an AT plate side around a new coordinate axis X' with respect to a new coordinate axis Y' resulting from rotating the crystal plate around the Z axis of the crystal whose crystal axes are X, Y, Z at an angle (ϕ1) within the range of a reference angle from 1° 30' to 13° .



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CLAIMS

[Claim(s)]

[Claim 1] rectangular coordinates -- a shaft -- X -- Y -- Z -- a crystallographic axis -- ** -- carrying out -- Xtal -- a crystal -- the Z-axis -- the surroundings -- criteria -- an angle -- one -- a degree -- 30 -- a minute -- from -- 13 -- a degree -- a range -- it is -- an angle (phi 1) -- having rotated -- new -- an axis of coordinates -- Y -- ' -- a shaft -- receiving -- a normal of a quartz-plate side -- making -- an angle (phi 2) -- new -- a quartz resonator using a quartz plate which is in an AT-cut side in a range for 50 minutes 36 degrees from 10 minutes criteria angle 35 degrees around an axis-of-coordinates X'shaft, respectively.

DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001]

[The technical field to which invention belongs] This invention relates to the quartz resonator of the quartz plate which has a new cutting angle from a crystallographic axis, and carries out thickness slip vibration.

[0002] In this invention, since the electrical characteristics from which NY cut and its quartz plate are defined as NY board, and the quartz resonator is defined as NY board quartz resonator, and the quartz resonator using a quartz plate and its quartz plate serves as a base in new angle cutting are made the same, both are defined as the same thing and treated.

[0003]

[Description of the Prior Art] Conventionally, quartz plates, such as AT and a BT cut, are mainly used for the quartz resonator which carries out thickness slip vibration (respectively henceforth AT and a BT cut), and quartz plates, such as FC, IT, and SC cut, are known (respectively henceforth FC, IT, and SC board). However, AT and a BT cut manage severely not rotating X and a Y-axis around the Z-axis, and are [about / about 35 degree 00 minutes thru/or, and 35 degree 30 minutes and, and] to a Y-axis, respectively about a plate surface normal. -They are 47 degrees thru/or the plate surface leaned -51 degrees. Therefore, about cutting and an angle sorting activity, it is comparatively easy. On the other hand, an AT cut is after-mentioned [number 1] which determines the configuration of the frequency temperature characteristic deltaf/fo as shown in the typical temperature characteristics a and b of drawing 1 . The effect of the 3rd temperature characteristic gamma is large in a ****** characteristic, the configuration which has top-most vertices near the reference temperature (for example, 25-degreeC) cannot be made, and the maximum change width of face of the temperature characteristic is enlarged. The quartz resonator by this AT cut is used for many devices as a common crystal oscillator large now and a crystal oscillator with which that frequency temperature characteristic is compensated using a thermistor. However, at the object for a mobile radio telephone which is increasing for example with diversification of amount of information in recent years, it may need to hold down frequency tolerance within **2 ppm by -20-degreeC-60-degreeC. In such a case, although the difference with the possible adjustment control to the precise quartz resonator in 1.0 ppm level and the configuration of the frequency temperature characteristic between oscillators is very important and the very small difference of the 3rd temperature characteristic gamma serves as an important key which determines success or failure That it is very difficult to meet the demand, and the maximum change width of face is large has the conditions of a use

range restricted also with increase of the loss of circuit by the thermistor as the 3rd temperature characteristic gamma which the range of an AT cut has.

[0004] although it is easy to make the configuration in which the effect of secondary temperature characteristics beta has top-most vertices large and convex near the reference temperature as a BT cut is show in the typical temperature characteristics c and d of drawing 2 -- coincidence -- the maximum change width of face of the property of the large temperature requirement where the effect of primary temperature characteristics alpha is also large -- the degree of pole -- large -- carry out -- the crystal oscillator of high degree of accuracy -- it cannot be use -- moreover , the temperature compensation -- **** -- it is restrict to a narrow temperature requirement , and the loss of circuit becomes large and is also disqualified .

[0005] It rotates. moreover, the surrounding angle phi 1 of the Z-axis as shown in drawing 3 -- it [its] about 15 degrees, 19degree6', and 22degree24' -- Y'shaft is also received around an axis-of-coordinates X'shaft. the normal of a quartz-plate side -- new -- FC and IT which leaned a certain angle range phi 2, respectively, and SC ****** -- although it is possible to make the configuration which primary temperature characteristics alpha are large, and the 3rd temperature characteristic gamma increases to negative, and has top-most vertices near the reference temperature, the maximum change width of face of the property of a large temperature requirement also increases. It differs in the purpose of use from each feature which it has. Therefore, for example As opposed to for example, -20-degreeC-60-degreeC of the temperature compensated crystal oscillator which FC board which sets point-of-inflection temperature to 50-degreeC has the purpose of use by the side of the elevated temperature more than 25-degreeC, IT, and SC board in the purpose of use to the stability of the support which makes a stress sensitivity coefficient smallness, and is current needed For using it in adjustment of the maximum change width of face of the ******** temperature characteristic, and its configuration, it is disqualified. Moreover, the surrounding angle of rotation phi 1 of the Z-axis is large, in addition, the inclination phi 2 of a normal is also started to the present synthetic-rock-crystal rough, and loss is also large.

[0006]

[Problem(s) to be Solved by the Invention] the need for the high elaboration of a quartz resonator -- following -- high [of a maximum change width of face of the frequency temperature characteristic of quartz resonator improvement-side and the circuit side of a quartz resonator and a crystal oscillator, and the mutual temperature characteristic] -- the temperature compensation by precise adjustment is newly a technical technical problem important for a quartz resonator. The technical problem of this invention sets the frequency temperature characteristic of the conventional quartz resonator to a large temperature requirement. Reduce the maximum change width of face of frequency change, in using it without compensating (usually henceforth the case of use), use is possible in the practical range, and temperature compensation is carried out. In using it (henceforth the case of compensation use), it aims at offer of the quartz resonator by the new quartz plate which has the configuration of the frequency temperature characteristic which adjusts the configuration of the property well with the frequency temperature characteristic by the side of the oscillator circuit of an extensive class, and comparatively few new quartz plates of logging loss.

[0007]

[Means for Solving the Problem]

[Drawing 3] It is alike and the shown **** rectangular coordinates shafts X, Y, and Z a crystallographic

axis -- ** -- carrying out -- Xtal -- a crystal -- the Z-axis -- the surroundings -- criteria -- an angle -- one -- a degree -- 30 -- a minute -- from -- 13 -- a degree -- a range -- it is -- an angle (phi 1) -- having rotated -- new -- an axis of coordinates -- Y -- ' -- a shaft -- receiving -- the angle (phi 2) which the normal of a quartz-plate side makes -- new -- by being in an AT-cut side in the range for 50 minutes 36 degrees from 10 minutes criteria angle 35 degrees around an axis-of-coordinates X'shaft, respectively the quartz resonator using the quartz plate (said NY board) constituted -- the primary temperature characteristics [secondary / 3rd] alpha, beta, and gamma -- smallness -- in the range the maximum change width of face which has convex top-most vertices near the reference temperature -- smallness -- the frequency temperature characteristic is realized and it has consistency at a precision in the configuration of the temperature characteristic by the side of the circuit of the crystal oscillator with which the configuration of the property becomes various in a large temperature requirement, and since there is also comparatively still little logging loss, a means effective in solution of said technical problem is offered.

[0008] In this invention, angle tolerance of the threshold value of a criteria angle is made into -30 and +0 minute to 10 minutes here surroundings 35 degrees of surroundings 1-time 30 minutes and X'shaft of the Z-axis, and it is defined as -0 and +30 minutes to 50 minutes 13 degrees surroundings 36 degrees of X'shaft the surroundings of the Z-axis. The value of the above-mentioned tolerance of a marginal criteria angle is what was defined in consideration of distinction of biaxial rotation, the difference in the quality of the material of synthetic rock crystal and that a marginal angle can usually be distinguished comparatively easily using a measuring device whenever [X line-angle / of the accuracy of level], and others, and completely differs from the allowable deviation of the angle on the layout for giving the frequency temperature characteristic required for a quartz resonator.

[0009] The operation which the solution means of this invention makes is explained below. Generally frequency temperature characteristic deltaf/fo of a quartz plate is following [Equation 1]. It can express with a formula.

[Equation 1]

$$\Delta f / f = \alpha (T - T0) + \beta (T - T0)^2 + \gamma (T - T0)^3$$

alpha, beta, and gamma show T and, as for the primary temperature characteristic [secondary / 3rd] and T0, arbitration temperature, reference temperature, ^2, and ^3 show a square and a cube mark here, respectively. alpha, beta, and gamma are mainly dependent on the angle of the above phi1 and phi2, respectively, and also the configuration of actual frequency temperature characteristic deltaf/fo becomes settled strictly also depending on many factors, such as a configuration of a quartz plate, the ratio r of the juxtaposition capacity CO of a quartz resonator, and the serial equivalent capacity C1 (the ratio is called capacity factor below), the load-carrying capacity CL of an oscillator circuit, and a temperature coefficient of CO and CL.

[0010] the configuration of the frequency temperature characteristic according [NY board of this invention] to the conditions of a quartz plate, the conditional factor of an oscillator circuit, etc. -- corresponding -- phi1 and phi2 of said angle within the limits -- each is set up. At the appropriate time, compared with the quartz plate of the conventional thickness slip vibration, the maximum change width of face decreases and frequency temperature characteristic deltaf/fo which becomes settled according to an operation of the temperature characteristics alpha, beta, and gamma which it has improves by the large temperature requirement, for example, -30-degreeC, thru/or 80-degreeC. therefore, the case of

usually use -- current -- the engine performance more than the AT cut currently used widely and an EQC is demonstrated. In the configuration of the temperature characteristic of an oscillator circuit, with an opposite sign, a compensation temperature range is comparatively well similar, and, in the case of compensation use, adjusts the configuration of the temperature characteristic of a quartz resonator rather than an AT cut at for example, -30-degreeC thru/or 80-degreeC. Therefore, a good result is obtained to the temperature compensation on condition of there being few differences of both. NY board in the angle range of phi1 and phi2 which have the temperature characteristics alpha, beta, and gamma which become various adjusted on the conditions of the oscillator circuit of an extensive class is [Equation 1]. The suitable role for solution of a technical problem can be played according to the operation which ****(ed).

[0011] Moreover, the Y cut thru/or Z disc synthetic-rock-crystal rough used widely now is the material of the letter of a rectangular parallelepiped block with the surface which usually meets a crystallographic axis. Therefore, when rotating and cutting down a quartz plate around the Z-axis and the X-axis, according to tanphi1, the material loss by logging increases, so that phi1, phi2, especially phi 1 are large. Although the conventional AT cut which makes phi 1 zero is the most advantageous, since phi 1 of NY board is in a still small range, tolerance has logging loss comparatively few.

[0012]

[Embodiment of the Invention] In the example which considered as the quartz resonator of frequency 12.8Mhz using various kinds of NY boards of this invention, and set the ratio ao of 20pf(s), the vibrator juxtaposition capacity CO, and load-carrying capacity CL to 0.1625 for the load-carrying capacity CL, frequency temperature characteristic deltaf/fo of many examples which usually contain the threshold value of the criteria angle to the case of use and the case of compensation use, respectively is shown in the following drawings.

[0013]

[Example] Drawing 4 is the example ** indicated each property after compensation adjusted in the temperature requirement of -20-degreeC-60-degreeC in the Colpitts mold oscillator circuit where in usually use ** has the thermistor B constant 2155 before compensation, and ** has ** in the case of compensation use to be in abbreviation phi1= 1-degree30'.

[0014] Drawing 5 is the example ** indicated each property after compensation in which the Colpitts mold oscillator circuit where in usually use ** has the thermistor B constant 3025 before compensation, and ** has ** in the case of compensation use was adjusted in the above-mentioned temperature requirement to be in abbreviation phi1=4 degree.

[0015] Drawing 6 is the example ** indicated each property after compensation in which the Colpitts mold oscillator circuit where in usually use ** has the thermistor B constant 3025 before compensation, and ** has ** in the case of compensation use was adjusted in the above-mentioned temperature requirement to be in abbreviation phi1=7 degree.

[0016] Drawing 7 is set at abbreviation phi1=10 degree. **10 In ****** use, **11 In the case of ****** use, before compensation and **12 ** **11 It is the example which showed each property after compensation which the Colpitts mold oscillator circuit which has the thermistor B constant 3025 was made to adjust in the above-mentioned temperature requirement.

[0017] Drawing 8 is set at abbreviation phi1=13 degree. **13 In ****** use, **14 In the case of ****** use, before compensation and **15 ** **14 It is the example which showed each property after compensation

which the Colpitts mold oscillator circuit which has the thermistor B constant 3025 was made to adjust in the above-mentioned temperature requirement. phi 2 in many above-mentioned examples takes the value of 35 degree18'<phi2<36 degree47' here, respectively.

[0018] It is [a table 1], respectively about a thing [NY board and the conventional quartz plate / using / in the usually use (near top-most-vertices temperature C of 25 degrees) about the maximum change width of face of deltaf/fo between -30 degreeC-80 degreeC / the compensation back as the respectively same conditions by example drawing 4 , drawing 5 , drawing 6 , drawing 7 , and drawing 8 in compensation use]. It is alike and is shown.

[A table 1]

		−30°C～80°C	−20°C～60°C
	φ1	通常使用の場合	補償使用の場合	補償後
	(degree)	最大変化幅(PPM)	最大変化幅(PPM)	(PPM)
NY板	1.5	12	28	±1.4
	4	12	25	±1.0
	7	12	22	±0.8
	10	18	32	±1.3
	13	26	43	±1.4
AT板	0	13	44	±2.0
BT板	0	126	310	不適
FC板	15	32	99	不適
IT板	19.4	44	130	不適
SC板	22.4	55	155	不適

[A table 1] Each property of NY board of ******** shows that the maximum change width of face in -30-degreeC-80-degreeC of frequency temperature characteristic deltaf/fo is decreased from AT, BT, conventional FC and conventional IT, SC board, etc. When carrying out especially temperature compensation, it is shown that the property at the time of making an oscillator circuit adjust these NY boards can be set to **1 thru/or less than **1.4 ppm in -20 degrees - 60 degreeC. Moreover, NY board of this invention shows a property with the same almost said of phi 1 other than the example hung up here, and the thing of a setup of phi 2.

[0019] As mentioned above, by [, such as a factor by the conditions by the side of an oscillator circuit,] in addition to this setting up phi1 and phi2 if needed, according to an operation of the primary temperature characteristics [secondary / 3rd] alpha, beta, and gamma, NY board of this invention covers a large temperature requirement, and acquires the configuration of the suitable frequency temperature characteristic for temperature compensation good.

[0020]

[Effect of the Invention] The quartz resonator with NY board of this invention is set to the frequency temperature characteristic, as an example shows numerically. The maximum change width of face in a temperature requirement Can make it decrease rather than what is depended on the conventional quartz plate, when it is usually use, improve frequency tolerance conventionally, and an opposite sign may be used and the case of compensation use makes the configuration of the property by the side of an oscillator circuit adjust the configuration of the temperature characteristic in a large temperature requirement. A

good compensation effect Since it is obtained, the effect of contributing to the industrial value when raising the engine performance is large.

[0021] Moreover, the effect of NY board having comparatively little logging loss from synthetic-rock-crystal rough, ending, and contributing to the industrial value with the improvement in the engine performance of a quartz resonator is large.

[Translation done.]

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]

[Drawing 1] It is drawing having shown the example of the frequency temperature characteristic of the conventional AT cut.

[Drawing 2] It is drawing having shown the example of the frequency temperature characteristic of the conventional BT cut.

[Drawing 3] It is drawing having shown axis-of-coordinates rotation of the crystallographic axis of Xtal.

[Drawing 4] In drawing having shown the example of the frequency temperature characteristic of phi1= 1-degree30' of NY board of this invention

** In the case of usually use

** It is a thing before the compensation in the case of ** temperature compensation, and after compensation.

[Drawing 5] In drawing having shown the example of the phi1=4 degree frequency temperature characteristic of NY board of this invention

** In the case of usually use

** It is a thing before the compensation in the case of ** temperature compensation, and after compensation.

[Drawing 6] In drawing having shown the example of the phi1=7 degree frequency temperature characteristic of NY board of this invention

** In the case of usually use

** It is a thing before the compensation in the case of ** temperature compensation, and after compensation.

[Drawing 7] In drawing having shown the example of the phi1=10 degree frequency temperature characteristic of NY board of this invention

**10 In usually, the case of use

**11 **12 It is a thing before the compensation in the case of temperature compensation, and after compensation.

[Drawing 8] In drawing having shown the example of the phi1=13 degree frequency temperature characteristic of NY board of this invention

**13 In usually, the case of use

**14 **15 It is a thing before the compensation in the case of temperature compensation, and after compensation.

[Description of Notations]

X, Y, Z Rectangular coordinates shaft of a crystal

X', Y' X, new axis of coordinates of a Y-axis

phi 1 Surrounding angle of rotation of the axis-of-coordinates Z-axis

phi 2 new -- angle which surrounding Y'shaft and the surrounding plate surface normal of an axis-of-coordinates X'shaft make

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[Translation done.]

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審査請求　未請求　請求項の数１　書面　（全　６　頁）

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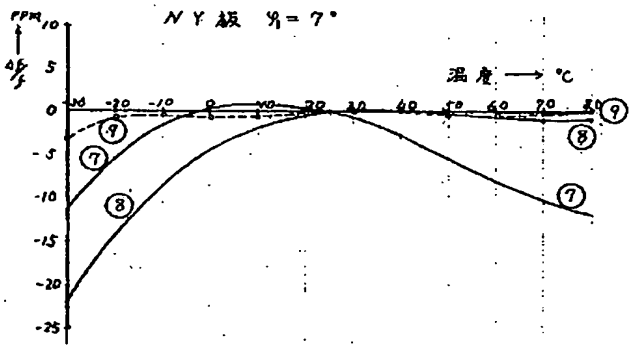
(54)【発明の名称】　水晶振動子

(57)【要約】

【課題】　本発明は水晶振動子の周波数温度特性を広い温度範囲において周波数変化の幅を減じ，補償をしない通常使用の場合には実用的な周波数温度特性をもって使用ができ，また補償を必要とする場合にはその特性の形状を広い範囲の種類の発振回路側の周波数温度特性の形状に類似しより良い整合を得ることができるような周波数温度特性を有し，また切り出し損失の比較的少ない新規な水晶振動子の提供を目的とする。

【解決手段】　直交座標軸Ｘ，Ｙ，Ｚを結晶軸とする水晶結晶のＺ軸の回りに基準角度１度３０分から１３度の範囲にある角度（φ１）で回転した新座標軸Ｙ´軸に対し，水晶板面の法線のなす角度（φ２）が新座標軸Ｘ´軸の回りでＡＴ板側にそれぞれ基準角度３５度１０分から３６度５０分の範囲にある水晶板を用いた水晶振動子によって課題の解決をはかる。



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【特許請求の範囲】

【請求項１】直交座標軸Ｘ，Ｙ，Ｚを結晶軸とする水晶結晶のＺ軸の回りに基準角度１度３０分から１３度の範囲にある角度（φ１）で回転した新座標軸Ｙ´軸に対し，水晶板面の法線のなす角度（φ２）が新座標軸Ｘ´軸の回りでＡＴ板側にそれぞれ基準角度３５度１０分から３６度５０分の範囲にある水晶板を用いた水晶振動子。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明は，結晶軸からの新規な切断角度を有して厚み滑り振動をする水晶板の水晶振動子に関する。

【０００２】本発明においては，新規な角度切断をＮＹカット，その水晶板をＮＹ板，その水晶振動子をＮＹ板水晶振動子と定義し，また水晶板とその水晶板を用いた水晶振動子とは基礎となる電気的特性を同じくするので両者を同一ものと定義して扱う。

【０００３】

【従来の技術】従来，厚み滑り振動をする水晶振動子には主としてＡＴ，ＢＴカット等の水晶板が使用され（以下それぞれＡＴ，ＢＴ板という），またＦＣ，ＩＴ，ＳＣカット等の水晶板が知られている（以下それぞれＦＣ，ＩＴ，ＳＣ板という）。しかしながら，ＡＴ，ＢＴ板はＺ軸の回りにＸ，Ｙ軸を回転させないことを厳しく管理して，板面法線をＹ軸に対して，それぞれ約３５度００分乃至３５度３０分及び約－４７度乃至－５１度傾けた板面である。そのために，切断作業，角度選別作業に関しては比較的容易である。しかしその反面で，ＡＴ板は図１の代表的な温度特性ａ，ｂに示すように，その周波数温度特性Δｆ／ｆｏの形状を決定する後記【数１】の温度指数の中で３次温度指数γの影響が大きく，基準温度（例えば２５°Ｃ）近傍に頂点を有する形状を作り得ず，温度特性の最大変化幅を大きくする。このＡＴ板による水晶振動子は現在広く一般の水晶発振器，またサーミスターを用いてその周波数温度特性を補償する水晶発振器として多くの機器に使用されている。しかしながら，例えば近年情報量の多様化に伴って増加している移動無線電話用では－２０°Ｃ～６０°Ｃで，周波数許容偏差を±２ｐｐｍ以内に抑え込むことを必要とする場合がある。そのような場合，１．０ｐｐｍレベルでの精密な水晶振動子と発振器相互の周波数温度特性の形状に対する整合制御が可能か否かの差は極めて重要であり，３次温度指数γの微少差が成否を決定する重要な鍵となるが，ＡＴ板の範囲の有する３次温度指数γではその要求に応えることは極めて困難であり，また最大変化幅の大きいことはサーミスターによる回路損失の増大をも伴って使用範囲の条件を制限される。

【０００４】ＢＴ板は図２の代表的な温度特性ｃ，ｄに示すように，２次温度指数βの影響が大きく基準温度近傍に上に凸の頂点を有する形状を作ることは容易であるが同時に１次温度指数αの影響も大きく広い温度範囲の特性の最大変化幅を極度に大きくし高精度の水晶発振器には使用できず，またその温度補償は極く狭い温度範囲に限られ回路損失も大きくなって不適格である。

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【０００５】また図３に示すようなＺ軸の回りの角度φ１をそれぞれ約１５°，１９°６´，２２°２４´回転して水晶板面の法線を新座標軸Ｘ´軸の回りにＹ´軸に対してもそれぞれある角度範囲φ２を傾けたＦＣ，ＩＴ，ＳＣ板おいて，１次温度指数αが大きく，３次温度指数γが負に増大し基準温度近傍に頂点を有する形状を作ることは可能であるが広い温度範囲の特性の最大変化幅も増大する。従って，それぞれの有する特徴から使用目的を異にし，例えば、変曲点温度を５０°ＣとするＦＣ板は２５°Ｃ以上の高温側での使用目的，ＩＴ，ＳＣ板は応力感度係数を小とする支持の安定性に対する使用目的にあり，現在必要とする温度補償水晶発振器の，例えば－２０°Ｃ～６０°Ｃに対しては周波数温度特性の最大変化幅，またその形状の整合において使用することには不適格である。またＺ軸の回りの回転角度φ１が大きく，法線の傾きφ２も加え現行の人工水晶原石に対しては切り出し損失も大きい。

【０００６】

【発明が解決しようとする課題】水晶振動子の高精密化の必要性に伴い，水晶振動子の周波数温度特性の最大変化幅の改善ならびに水晶振動子と水晶発振器の回路側と相互間の温度特性の高精密な整合による温度補償は新たに水晶振動子にとって重要な技術的課題である。本発明の課題は，従来の水晶振動子の周波数温度特性を広い温度範囲において周波数変化の最大変化幅を減じて，補償をしないで使用する場合（以下通常使用の場合という）には実用的な範囲で使用ができ，また温度補償をして使用する場合（以下補償使用の場合という）にはその特性の形状を広範な種類の発振回路側の周波数温度特性と良く整合する周波数温度特性の形状を有する新規な水晶板，および切り出し損失の比較的少ない新規な水晶板による水晶振動子の提供を目的とする。

【０００７】

【課題を解決するための手段】【図３】に示す如き直交座標軸Ｘ，Ｙ，Ｚを結晶軸とする水晶結晶のＺ軸の回りに基準角度１度３０分から１３度の範囲にある角度（φ１）で回転した新座標軸Ｙ´軸に対し，水晶板面の法線のなす角度（φ２）が新座標軸Ｘ´軸の回りでＡＴ板側にそれぞれ基準角度３５度１０分から３６度５０分の範囲にあることによって構成される水晶板（前記ＮＹ板）を用いた水晶振動子は１次，２次，３次の温度指数α，β，γが小なる範囲で，基準温度近傍で上に凸の頂点を有する最大変化幅の小なる周波数温度特性を実現し，その特性の形状が広い温度範囲で種々なる水晶発振器の回路側の温度特性の形状に精密に

整合し，また切り出し損失も比較的未だ少ないので前記課題の解決に有効な手段を提供する。

【０００８】ここに本発明においては基準角度の限界値の角度許容差をＺ軸の回り１度３０分，Ｘ´軸の回り３５度１０分に対してはー３０，＋０分とし，またＺ軸の回り１３度，Ｘ´軸の回り３６度５０分に対してはー０，＋３０分と定義する。限界基準角度の上記許容差の値は２軸回転の判別，人工水晶の材質の差異，また普通＊

＊レベルの確度のＸ線角度測定装置を用いて限界角度を比較的容易に判別し得ること，その他を考慮して定めたもので，水晶振動子に必要な周波数温度特性を与えるための設計上の角度の許容偏差とは全く異なるものである。

【０００９】本発明の解決手段がなす作用を次に説明する。一般に水晶板の周波数温度特性Δｆ／ｆｏは次の【数１】式で表すことができる。

【数１】

$$\Delta f/f = \alpha (T - T0) + \beta (T - T0)^2 + \gamma (T - T0)^3$$

ここにα，β，γはそれぞれ１次，２次，３次の温度指数，Ｔ，Ｔ０はそれぞれ任意温度，基準温度，＾２、＾３はそれぞれ二乗，三乗記号を示す。α，β，γはそれぞれ前記φ１，φ２の角度に主として依存するほかに厳密には水晶板の形状，水晶振動子の並列容量ＣＯと直列等価容量Ｃ１の比ｒ（以下その比を容量比という），発振回路の負荷容量ＣＬ，及びＣＯ，ＣＬの温度係数等多くの因子にも依存して実際の周波数温度特性Δｆ／ｆｏの形状が定まる。

【００１０】本発明のＮＹ板は水晶板の条件及び発振回路の条件因子等による周波数温度特性の形状に対応して前記角度範囲内のφ１，φ２それぞれを設定する。しかるときはその有する温度指数α，β，γの作用によって定まる周波数温度特性Δｆ／ｆｏは従来の厚み滑り振動の水晶板に比べて広い温度範囲例えばー３０°Ｃ乃至８０°Ｃで最大変化幅が減少し改善される。従って，通常使用の場合で現在広く使用されているＡＴ板と同等以上の性能を発揮する。補償使用の場合では補償温度範囲が例えばー３０°Ｃ乃至８０°Ｃで，水晶振動子の温度特性の形状はＡＴ板よりも発振回路の温度特性の形状に反対符号で比較的よく類似し整合する。従って，両者の差の少ないことを条件とする温度補償に対して良好な結果が得られる。広範な種類の発振回路の条件に整合する，種々なる温度指数α，β，γを有するφ１，φ２の角度範囲にあるＮＹ板は

【数１】に則した作用によって課題の解決に適切な役割を果たすことができる。

【００１１】また，現在広く使用されているＹ板乃至Ｚ板人工水晶原石は通常結晶軸に沿う表面をもった直方体ブロック状の素材である。従って水晶板をＺ軸、Ｘ軸の回りに回転して切り出す場合，φ１，φ２特にφ１が大きい程ｔａｎφ１に応じて切り出しによる素材損失は増大する。φ１を零とする従来のＡＴ板が最も有利であるが，ＮＹ板のφ１は未だ小さい範囲にあるので，切り出し損失は比較的少く許容範囲にある。

【００１２】

【発明の実施の形態】本発明の各種のＮＹ板を用いて周波数１２．８Ｍｈｚの水晶振動子とし，その負荷容量ＣＬを２０ｐｆ，振動子並列容量ＣＯと負荷容量ＣＬの比ａｏを０．１６２５とした例において，それぞれ通常使用の場合と補償使用の場合に対する基準角度の限界値を含む諸例の周波数温度特性Δｆ／ｆｏを以下の図に示す。

【００１３】

【実施例】図４は約φ１＝１°３０´において，①は通常使用の場合，②は補償使用の場合で補償前，及び③は②をサーミスターＢ定数２１５５を有するコルピッツ型発振回路において－２０°Ｃ～６０°Ｃの温度範囲で整合させた補償後のそれぞれの特性を示した例である。

【００１４】図５は約φ１＝４°において，④は通常使用の場合，⑤は補償使用の場合で補償前，及び⑥は⑤をサーミスターＢ定数３０２５を有するコルピッツ型発振回路に上記温度範囲で整合させた補償後のそれぞれの特性を示した例である。

【００１５】図６は約φ１＝７°において，⑦は通常使用の場合，⑧は補償使用の場合で補償前，及び⑨は⑧をサーミスターＢ定数３０２５を有するコルピッツ型発振回路に上記温度範囲で整合させた補償後のそれぞれの特性を示した例である。

【００１６】図７は約φ１＝１０°において，▲１０▼は通常使用の場合，▲１１▼は補償使用の場合で補償前，及び▲１２▼は▲１１▼をサーミスターＢ定数３０２５を有するコルピッツ型発振回路に上記温度範囲で整合させた補償後のそれぞれの特性を示した例である。

【００１７】図８は約φ１＝１３°において，▲１３▼は通常使用の場合，▲１４▼は補償使用の場合で補償前，及び▲１５▼は▲１４▼をサーミスターＢ定数３０２５を有するコルピッツ型発振回路に上記温度範囲で整合させた補償後のそれぞれの特性を示した例である。ここに，上記諸例におけるφ２はそれぞれ３５°１８´＜φ２＜３６°４７´のうちの値を採る。

【００１８】実施例図４，図５，図６，図７，図８でー３０°Ｃ～８０°Ｃの間におけるΔｆ／ｆｏの最大変化幅について，通常使用の場合（頂点温度２５°Ｃ近傍），補償使用の場合，補償後をそれぞれ同じ条件としてＮＹ板と従来の水晶板と比較したものをそれぞれ【表１】に示す。

【表１】

	φ1 (degree)	−30°C～80°C 通常使用の場合 最大変化幅(PPM)	−30°C～80°C 補償使用の場合 最大変化幅(PPM)	−20°C～60°C 補償後 (PPM)
NY板	1.5	12	28	±1.4
	4	12	25	±1.0
	7	12	22	±0.8
	10	18	32	±1.3
	13	26	43	±1.4
AT板	0	13	44	±2.0
BT板	0	126	310	不適
FC板	15	32	99	不適
IT板	19.4	44	130	不適
SC板	22.4	55	155	不適

【表１】は本発明のＮＹ板の特性がいずれも従来のＡＴ，ＢＴ，ＦＣ，ＩＴ，ＳＣ板等よりも周波数温度特性Δｆ／ｆｏの−３０°Ｃ～８０°Ｃにおける最大変化幅を減少させることを示している。特に温度補償する場合，これらのＮＹ板を発振回路に整合させたときの特性は−２０°～６０°Ｃにおいて±１乃至±１．４ｐｐｍ以内にすることができることを示している。また本発明のＮＹ板はここに掲げた実施例以外のφ１，φ２の設定のものについてもほぼ同様の特性を示す。

【００１９】上記のように本発明のＮＹ板は発振回路側の条件による因子等その他必要に応じてφ１，φ２を設定することにより１次，２次，３次の温度指数α，β，γの作用によって，広い温度範囲に亘り良好な，また温度補償に適切な周波数温度特性の形状を得る。

【００２０】

【発明の効果】本発明のＮＹ板による水晶振動子は実施例で数値的に示すように，その周波数温度特性において温度範囲内の最大変化幅を従来の水晶板によるものよりも減少させることができ，通常使用の場合は周波数許容偏差を従来よりも改善し，補償使用の場合は広い温度範囲でその温度特性の形状を発振回路側の特性の形状に反対符号でよく整合させて良好な補償効果を得られるので，性能を向上させる上でその工業的価値に貢献する効果は大きい。

【００２１】またＮＹ板は人工水晶原石からの切り出し損失が比較的少なくて済み，水晶振動子の性能向上とともにその工業的価値に貢献する効果は大きい。

【図面の簡単な説明】

【図１】従来のＡＴ板の周波数温度特性の例を示した図である。

【図２】従来のＢＴ板の周波数温度特性の例を示した図である。

【図３】水晶の結晶軸の座標軸回転を示した図である。

【図４】本発明のＮＹ板のφ１＝１°３０´の周波数温度特性の例を示した図で

①　通常使用の場合

②，③　温度補償の場合の補償前及び補償後のものである。

【図５】本発明のＮＹ板のφ１＝４°の周波数温度特性の例を示した図で

④　通常使用の場合

⑤，⑥　温度補償の場合の補償前及び補償後のものである。

【図６】本発明のＮＹ板のφ１＝７°の周波数温度特性の例を示した図で

⑦　通常使用の場合

⑧，⑨　温度補償の場合の補償前及び補償後のものである。

【図７】本発明のＮＹ板のφ１＝１０°の周波数温度特性の例を示した図で

▲１０▼　通常使用の場合

▲１１▼，▲１２▼　温度補償の場合の補償前及び補償後のものである。

【図８】本発明のＮＹ板のφ１＝１３°の周波数温度特性の例を示した図で

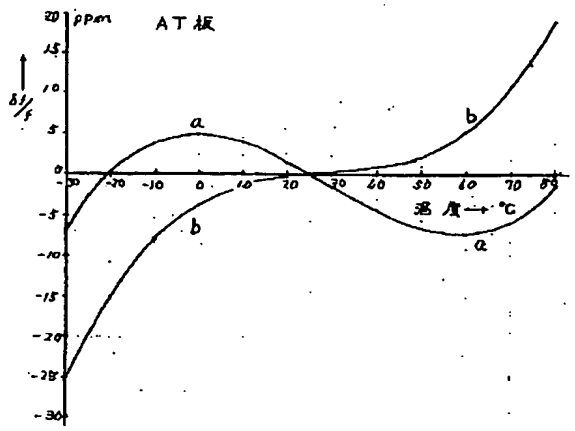
△１３▽　通常使用の場合

△１４▽，△１５▽　温度補償の場合の補償前及び補償後のものである。

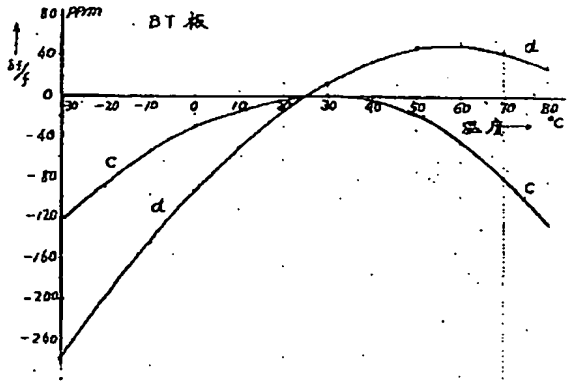
【符号の説明】

Ｘ，Ｙ，Ｚ	結晶の直交座標軸
Ｘ´，Ｙ´	Ｘ，Ｙ軸の新座標軸
φ１	座標軸Ｚ軸の回りの回転角度
φ２	新座標軸Ｘ´軸の回りのＹ´軸と板面法線のなす角

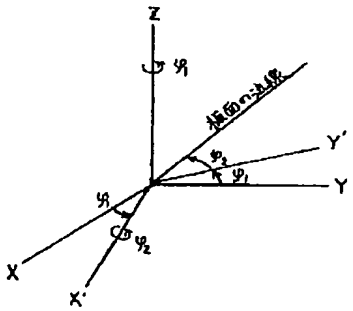
【図１】



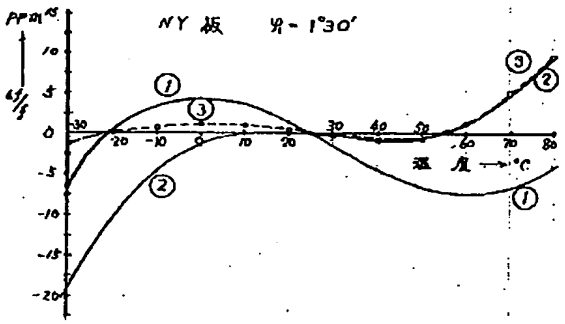
【図２】



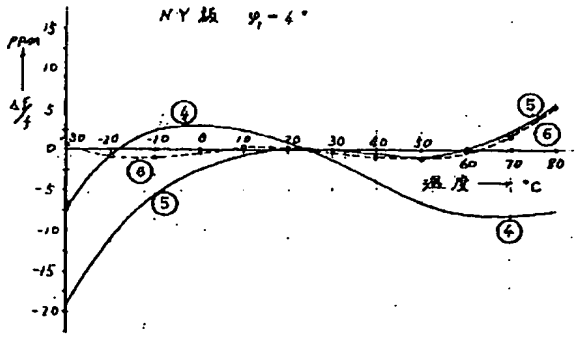
【図３】



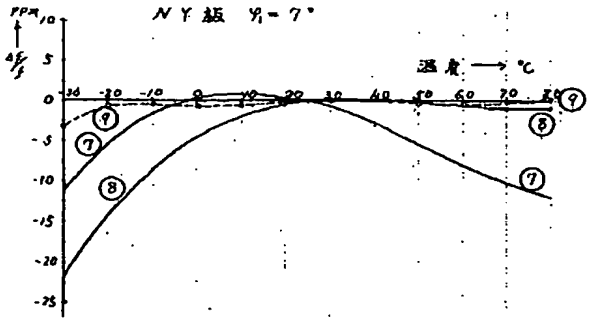
【図４】



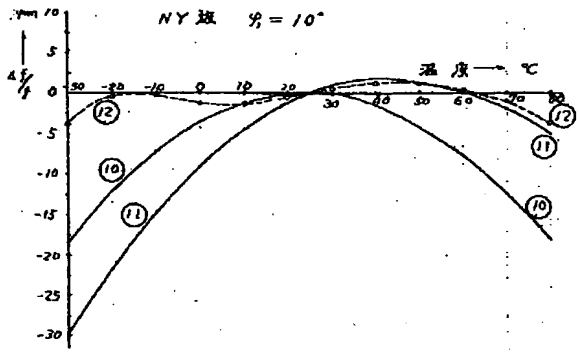
【図５】



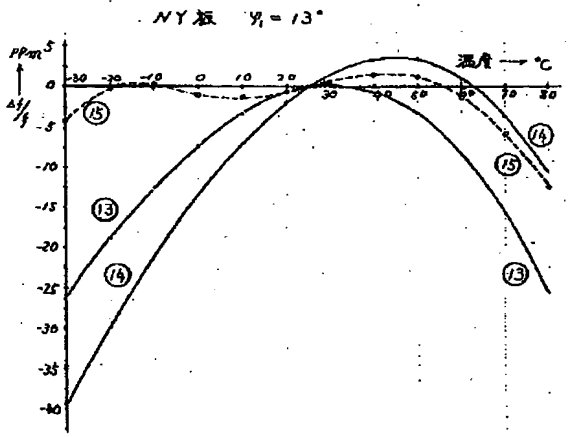
【図６】



【図７】


NY板 $\varphi_1 = 10°$
温度 → ℃
ppm
$\frac{\Delta f}{f}$
10
5
0
-5
-10
-15
-20
-25
-30
-50
-30
-10
0
10
20
30
40
50
60
70
80
12
10
11
12
11
10

【図８】


NY板 $\varphi_1 = 13°$
温度 → ℃
ppm
$\frac{\Delta f}{f}$
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-30
-20
-10
0
10
20
30
40
50
60
70
80
15
13
14
14
15
13